Discussion of: Olea, R.A. and Coleman, J.L., Jr., 2014. A Synoptic Examination of Causes of Land Loss in Southern Louisiana as Related to the Exploitation of Subsurface Geological Resources. Journal of Coastal Research, 30(5), 1025–1044.

Author: Turner, R. Eugene

Source: Journal of Coastal Research, 30(6) : 1330-1334

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/JCOASTRES-D-14-00076.1

Journal of Coastal Research	30	6	1330–1334	Coconut Creek, Florida	November 2014

DISCUSSION

www.cerf-jcr.org

Discussion of: Olea, R.A. and Coleman, J.L., Jr., 2014. A Synoptic Examination of Causes of Land Loss in Southern Louisiana as Related to the Exploitation of Subsurface Geological Resources. *Journal of Coastal Research*, 30(5), 1025–1044.

R. Eugene Turner

Department of Oceanography and Coastal Sciences
Louisiana State University
Baton Rouge, LA 70803, U.S.A.
euturne@lsu.edu

www.JCRonline.org

ABSTRACT

Turner, R.E., 2014. Discussion of: Olea, R.A. and Coleman, J.L., Jr., 2014. A synoptic examination of causes of land loss in southern Louisiana as related to the exploitation of subsurface geological resources. *Journal of Coastal Research*, 30(5), 1025–1044. *Journal of Coastal Research,* 30(6), 1330–1334. Coconut Creek (Florida), ISSN 0749-0208.

I comment on Olea and Coleman's (2014) conclusion that subsidence was the primary cause of the dramatic rise in Louisiana's coastal land losses in the last 100 years. The focus on subsidence combined with the omission of context for factors not related to subsidence (*e.g*., dredged canals), leaves the reader with the incorrect conclusion that anthropogenic factors observed to date are insignificant, and that coastal wetland losses are only driven by subsidence. I address this omission by discussing two points about anthropogenic influences: (1) dredged canals and (2) changes in sediment load from the watershed and its distribution. They omit quantitative inclusion of two signature symptoms of the cause-and-effect relationships at temporal and spatial scales. To whit, there are: direct relationships between canal density and land loss over decades and shorter intervals for the whole coast and individual estuaries, instances of indirect losses immediately after canal construction, an increase in ponding near dredged canals but not further away, and, evidence of effective hydrologic barriers created by the spoil bank above- and belowground. The view that geological subsidence exerts a top-down control on the net adjustment to changes in vertical space leads to the narrow view of restoration being modeled using the mineral soils for wetland soils comprised mostly of organics. Further, the decline in suspended sediment concentrations since the 1950s (from dam construction) needs to be put within the context of the landscape changes occurring when European colonization resulted in much higher rates of erosion. The restriction of exclusively geological factors driving land loss is, therefore, an incomplete view of what causes land loss in modern times—and a perhaps dangerously naïve basis for management decisions on this coast. I agree with their conclusions that (1) geological subsidence has not changed significantly in the last 100 years, (2) fluid withdrawal is an unlikely and unproven large enough force to cause the patterns in land loss across the deltaic plain, and (3) acceleration in sea level rise will rise to problematic levels in the near future.

ADDITIONAL INDEX WORDS: *Coastal wetland loss, Louisiana, dredging, subsidence, sediment supply.*

INTRODUCTION

Olea and Coleman (2014) present arguments for their conclusion that the causes of coastal land loss in coastal Louisiana are primarily restricted to three kinds of geological subsidence. These land losses, which are mostly wetland losses, are about 25% of the coastal land present in 1932 (Couvillion *et al.,* 2010), so this is a serious issue for many reasons. Olea and Coleman conducted a Monte Carlo simulation of glacial isostasy, isostatic adjustment, sediment compaction, faulting, and oil and gas production (representing fluid withdrawal) in an attempt to quantitatively estimate the relative contribution of each to land loss and eliminated fluid withdrawal as a significant factor. They concluded that these forms of subsidence were the primary cause of the observed land losses in the past 100 years. For example: "The loss seems to be the combined result of natural and anthropogenic causes that are behind primarily land subsidence" (Abstract); "The main natural factors contributing to coastal land loss in southern Louisiana are lithosphere flexture as a reaction to sediment loading, faulting, and sediment compaction" (p. 15). Their Table 3 acknowledges that there is an effect of dredged canals that might contribute up to 75% of the land loss, but then, they ignore these indirect effects in their conclusions, *e.g*., "Subsidence and sea level rise have been the land loss causes with continuous effect through time and space at least for the last 80

DOI: 10.2112/JCOASTRES-D-14-00076.1 received 27 April 2014; accepted in revision 1 May 2014; corrected proofs received 16 July 2014; published pre-print online 28 August 2014.

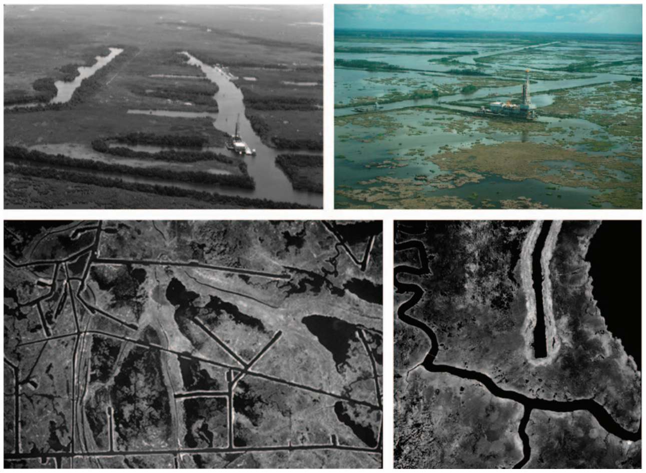

Figure 1. Photographs of dredged canals and their spoil bank in south Louisiana wetlands. The spoil bank has shrubs and trees on it. The individual wellhead is in the enlarged area at the end of the canal (called a *keyhole*). (Color for this figure is available in the online version of this paper.)

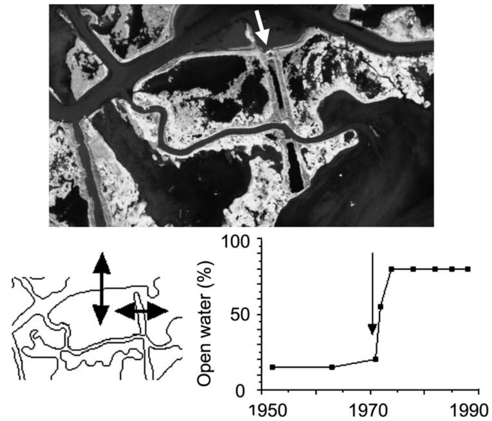

Figure 2. Land loss at one location occurring after a canal was dredged on the south side of Jug Lake, west of Houma, Louisiana. The area of adjacent wetland went from around 15% open water to 85% open water within 2 y after dredging. Adapted from Turner, Swenson, and Lee, 1994.

years with better records. Other factors seem to have had a more local or temporary influence" (p. 13). This leads to the conclusion that subsidence is directly related to land loss ("...complete elimination of this form of subsidence will likely result in no more than a 5% reduction of subsidence and coastal land loss"). The focus on subsidence from these four factors (lithosphere flexture, sediment loading, faulting, and compaction) and on sediment supply, combined with the omission of context for factors not related to subsidence (*e.g.*, dredged canals), leaves the reader with the incorrect conclusion that anthropogenic factors observed to date are insignificant and that it is only a matter of how much subsidence occurs. I address this omission herein by discussing two points about anthropogenic influences: (1) dredged canals, and (2) changes in sediment load from the watershed and its distribution.

DREDGED CANAL IMPACTS

Canals and the spoil banks created by disposal of the dredged materials cause wetland loss by the *direct* replacement of one habitat with another and the *indirect* consequences on local wetland hydrology. Examples of these features are shown in Figure 1. The total length of spoil banks in 1978 was about 17,894 km (Turner and Streever, 2002, Table 4.1), which is about twice the distance from Los Angeles, California, to London, England.

The total direct effects can be significant. A typical oil and gas canal is dredged to be about 4 to 5 m deep and 41 to 45 m wide, which is much wider and deeper than a natural channel in coastal wetlands. Baumann and Turner (1990) estimated that approximately 16.1% and 6.3% of the wetland loss in coastal Louisiana from 1955/56–78 was from the combined effect of canals and spoil banks, or canals alone, respectively. Britsch and Dunbar (1993) estimated that the 45,866 ha of constructed channels dredged from the 1930s to 1990 (in slightly different mapping units from Baumann and Turner, 1990) accounted for 12% of the total land loss during that interval.

The remaining 84% of wetland loss is from other causes, including the *indirect* impacts of canals. The specific mechanisms to explain these effects are not fully understood in each type of wetland or estuary, but changes in wetland hydrology are usually the key agent of change because the spoil bank and canal alter the patterns of water flow, *e.g.,* frequency of flooding and drying. Spoil banks, for example, are initially at least 1 m higher than the average tide, which changes the aboveground movements of water. The spoil weight compacts the soil beneath it (Nichols, 1959), thereby reducing belowground water flows (Swenson and Turner, 1987). One of the indirect impacts of this damming effect of spoil banks above- and belowground is waterlogging. Longer wetting cycles (waterlogging) may lead to toxic sulfide accumulations and may reduce the accumulation of soil organic matter; the same damming effect causes longer drying cycles, which leads to soil oxidation. Spoil banks can inhibit sedimentation rates (Cahoon and Turner, 1989). The combined effects of canals and spoil banks leads to pond formation within 2 km of the canal. More and larger ponds form with increases in the local density of spoil banks (Turner and Rao, 1990).

Regional or site-specific instances of these spatial and temporal relationships are available at many scales. One example involves a canal dredged on the south side of Jug Lake, west of Houma, Louisiana. The area of adjacent wetland went from around 15% open water to 85% open water within 2 years after dredging (Figure 2; Turner, Swenson, and Lee, 1994). Other examples can be seen in the rate at which the wetlands changed to open water for 27 salt marshes in the Barataria, Breton Sound, and Terrebonne estuaries (exclusive of the canal area). The changes were measured for four intervals from 1955 to 1990, when wetland-loss rates rose, stabilized, rose again, and stabilized again. Open water area increased each time dredging increased and stabilized or declined slightly when dredging ceased (Bass and Turner, 1997).

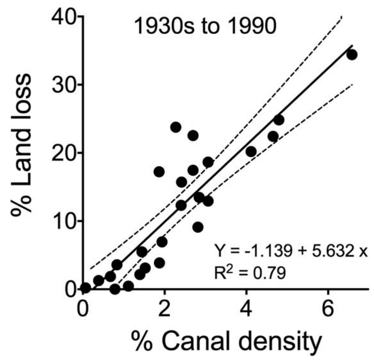

Figure 3. The relationship between canal density and land loss for the deltaic plain from the 1930s to 1990. The data shown are for 15-min quadrangle maps (roughly 664 km^2 each) for the deltaic plain, and exclude data for maps with <50% land area in the 1930s. The total area represented is 77% of the deltaic plain (12,872 km^2). The equation is for a simple linear regression of the data with a 95% confidence interval. Note the zero intercept. Adapted from data discussed in Turner, 1997.

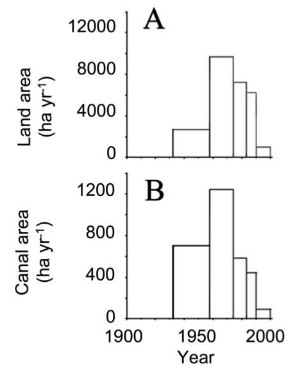

Figure 4. Temporal changes in (A) canal area, and (B) land loss for the entire Louisiana coast. There is a temporal coherence of dredging and land loss for the Louisiana coast from the 1930s to 2001. Adapted from data discussed in Turner, 1997.

There are several estimates of these indirect losses of land or wetland at an estuary scale, including the following four estimates.

A consensus estimate by 13 coastal scientists who were involved in a landmark study of the topic was that, from 1955/6 to 1978, the combined direct and indirect impacts of canals caused *at least* 30%–59% of the total coastal land loss in Louisiana (Turner and Cahoon, 1997).

Scaife, Turner, and Costanza (1983) used data on the density of canals *vs*. land loss in 7.5-minute quadrangle maps of estuarine wetlands of similar geology to estimate the background rate of land loss from all other factors in the absence of canals. Their estimate of the land loss from canals could then be calculated as the difference in the loss rates minus that background rate. Their resulting estimate for the deltaic plain was that 89% of the land loss was due to the direct and indirect effects of canals and the associated spoil banks.

Penland *et al*. (1996; an unpublished report) provided a subjective estimate that canals were the cause of 35% of the wetland losses for the Louisiana coast.

Turner (1997) presented an analysis suggesting that the best explanation among four competing hypotheses explaining the wetland loss in coastal Louisiana was that the combined effects of the direct and indirect impacts of canals and spoil banks were the more likely cause of these land losses (and not subsidence, river levees, salinity stress, or sediment starvation).

Although these estimates are not in complete agreement, it is clear that a significant amount of wetland area lost along this coast is attributable to the combined direct and indirect impacts of canals and spoil banks.

Two grand patterns are particularly striking, I think, and cannot be ignored in these discussions. The first is the relationship between canal density and land loss for the entire deltaic plain (based on 15-min quadrangle maps) from the 1930s to 1990. The loss rates are directly related to land loss in a dose–response manner, and there is a zero intercept (Figure 3). The second is that there is a temporal coherence between dredging and land loss for the Louisiana coast from the 1930s to 2001 (Figure 4). Land loss rates increased and declined as dredging increased and declined.

The rosy picture given by Olea and Coleman (2014) of significant reduction in impacts from dredged canals is a misrepresentation of the actual case. Canal construction may be less than it was in the 1960s, but the reasons have little to do with management. Simply put, the recoverable mineral reserves are dwindling, and the canals already in place are able to reach the wellhead locations using the same drilling-access methods.

It seems to me, therefore, that Olea and Coleman (2014) omit a quantitative inclusion of a signature symptom in the cause-and-effect relationships at temporal (Figure 4) and spatial (Figure 3) scales. I agree with their conclusion that geological subsidence has not changed significantly in the past 100 years and that fluid withdrawal is an unlikely cause of the patterns of land loss across the deltaic plain and whether its force would be sufficient to do so remains unproven. How could the spatial variation, however, not be due to the dredging of canals if the subsidence is unchanged in time and space? If subsidence from fluid withdrawal is not the driver of land loss, then what other factor explains the observed land loss, the absence of loss a few kilometers away from a canal, the losses within 1 km of a canal, and the higher losses where the canals intersect and impound wetlands? Indeed, there is a direct relationship between land loss and dredging, and there is a zero intercept, regardless of whether those areas are near the coast or not. How could this be a result of salinity intrusion if the plant species are adapted to saline fluctuations, and there is no evidence of a coastwide intrusion of saltwater (Parsons *et al.,* 1999; Wiseman, Swenson, and Power, 1990)? If salinity were the driver, then wouldn't the losses per area of canal be higher in the fresh marshes and be the least in the salt marshes—*i.e*. the data in Figure 3 would be less robust? How else does one explain the rapid conversion to water when impounded, if not through a biogeochemical interaction affecting the organic mass that has accumulated over centuries and millennia and the modern-day living plant?

This discussion is not to ignore the essential limiting role of sediments comprising the geological structure upon which emergent coastal vegetation has anchored itself, grown, and accumulated soil organics over millennia. The inorganic volume in those surficial sediments is less than 4% (Turner, Swenson, and Milan, 2000). It is the dredging of canals that has affected the green "toupee" overlying the sediments, not the geological structure beneath the emergent vegetation. It is this organic layer that can be compromised when nutrient supply increases sufficiently to stimulate its decomposition and reduce live, belowground biomass, reducing soil strength and making it susceptible to storm-induced erosion (Deegan *et al.,* 2012; Swarzenski *et al.,* 2008). The health of the plants may become compromised with a higher rate of sea-level rise this century, erode at the edge, and migrate inland. I agree completely with the conclusion that acceleration in sea-level rise will become a driving force if it becomes greater than the presently observed limit in vertical accretion (Kearney and Turner, 2014).

SEDIMENT LOADING DECLINES

The second point is related to the "sediment deficit" view of wetland loss and the overstated role of sediment loading from the Mississippi River in controlling wetland gain and loss in the past 100 years. The picture painted is that sediment loading decreased with engineering features (*e.g.,* dams), and its distribution was constrained by flood-protection levees. Yes, sediment loading decreased from the 1880s to present, but the sediment load was higher after the expansion of Europeans into the watershed for 200 years and was so much higher then that the present load is about equal to the precolonization era after dams had been constructed and trapped 50% of the sediment flux upstream (Tweel and Turner, 2012). These culturally induced erosion and coastal accumulations are well known (Bruckner, 1986; Hughes, 1996). The precolonial shape at the river's terminus has grown and shrunk over decades as this loading fluctuated, but that is not the case for the deltaic plain to the north (Tweel and Turner, 2012). Further, the amount of sediments flowing overbank before flood-protection levees were built was about 2% of the river's load (Kesel, 1988), and its accumulation would be concentrated no more than a few kilometers from the riverbank (hence the formation of the riverbank levee). Hurricanes, in contrast, bring a larger amount of sediment, which is spread across the coast in a more democratic manner (Tweel and Turner, 2014).

Most of the deltaic plain soils are composed of organic matter, not mineral matter (Tweel and Turner, 2012). Omitting the role of belowground organic matter ignores an admittedly difficult complexity for the geologic-centric view of wetland loss; however, belowground organic matter hosts the consequential set of interactions driving the canal–wetland loss cause-and-effect relationships shown in Figures 3 and 4. Indeed, the view that geological subsidence exerts a top–down control on the net adjustment to changes in vertical space (*i.e.* from sea level rise above, or soil oxidation within) is an insufficient model for restoration. It leads to the narrow view of restoration being modeled on the basis of sediment flux, and acceptance of using the mineral soils of the receiving basin at the end of the Atchafalaya River and Mississippi River deltas as a legitimate model for restoration success (or failure) in organic soils. The restriction of exclusively geological factors driving land loss is, therefore, an incomplete view of what causes land loss in modern times—and a, perhaps dangerously, naïve basis for management decisions on this coast.

ACKNOWLEDGMENTS

I thank Doug Daigle, Paul Kemp, and Chris Swarzenski for their constructive comments on the draft manuscript.

LITERATURE CITED

Bass, A. and Turner, R.E., 1997. Relationships between salt marsh loss and dredged canals in three south Louisiana estuaries. *Journal of Coastal Research,* 13(3), 895–903.

Baumann, R.H. and Turner, R.E., 1990. Direct impacts of outer continental shelf activities on wetland loss in the central Gulf of Mexico. *Environmental Geology and Water Resources,* 15(3), 189–198.

Britsch, L.D. and Dunbar, J.B., 1993. Land loss rates: Louisiana coastal plain. *Journal of Coastal Research,* 9(2), 324–338.

Brückner, H., 1986. Man's impact on the evolution of the physical environment in the Mediterranean region in historical times. *GeoJournal,* 13(1), 7–17.

Cahoon, D.R. and Turner, R.E., 1989. Accretion and canal impacts in a rapidly subsiding wetland. II: feldspar marker horizon technique. *Estuaries,* 12(4), 260–268.

Couvillion, B.R.; Barras, J.A.; Steyer, G.D.; Sleavin, W.; Fischer, M.; Beck, H.; Trahan, N.; Griffin, B., and Hekman, D., 2011. *Land area change in coastal Louisiana from 1932 to 2010*. U.S. Geological Survey Scientific Investigation Map 3164, scale 1:265,000, pamphlet, 12p.

Deegan, L.A.; Johnson, D.S.; Warren, R.W.; Peterson, B.J.; Fleeger, J.W.; Fagherazzi, S., and Wollheim, W.M., 2012. Coastal eutrophication as a driver of salt marsh loss. *Nature,* 490(7420), 388–392.

Hughes, J.D., 1996. *Pan's Travail: Environmental Problems of the Ancient Greeks and Romans*. Baltimore, MD: Johns Hopkins University Press, 306p.

Kesel, R.H., 1988. The decline in the suspended load of the lower Mississippi River and its influence on adjacent wetlands. *Environmental Geology,* 11(3), 271–281.

Nichols, L.G., 1959. *Rockefeller Refuge Levee Study*. New Orleans: Louisiana Wildlife Fisheries Commission. Refuge Division Technical Report, 17p.

Olea, R.A. and Coleman, J.L., 2014. A synoptic examination of causes of land loss in southern Louisiana as they related to the exploitation of subsurface geologic resources. *Journal of Coastal Research,* In press.

Parsons, M.L.; Dortch, Q.; Turner, R.E., and Rabalais, N.N., 1999. Salinity history of coastal marshes reconstructed from diatom remains. *Estuaries,* 22, 1078–1089.

Penland, S.; Mendelssohn, I.A.; Wayne, L., and Britsch, L.D., 1996. *Natural and Human Causes of Coastal Land Loss in Louisiana*. Coastal Studies Institute and Wetland Biogeochemistry Institute, Louisiana State University: Baton Rouge, Louisiana.

Scaife, W.W.; Turner, R.E., and Costanza, R., 1983. Recent land loss and canal impacts in coastal Louisiana. *Environmental Management,* 7, 433–442.

Swarzenski, C.M.; Doyle, T.W.; Fry, B., and Hargis, T.G., 2008. Biogeochemical response of organic-rich freshwater marshes in the Louisiana delta plain to chronic river water influx. *Biogeochemistry,* 90, 49–63.

Swenson, E.M. and Turner, R.E., 1987. Spoil banks: effects on a coastal marsh water level regime. *Estuarine, Coastal and Shelf Science*, 24, 599–609.

Turner, R.E., 1997. Wetland loss in the northern Gulf of Mexico: Multiple working hypotheses. *Estuaries,* 20, 1–13.

Turner, R.E. and Cahoon, D.R. (eds.), 1987. *Causes of Wetland Loss in the Coastal Central Gulf of Mexico*. U.S. Minerals Management

Service Final Report No. 14-12-001-30252, Contract OCS Study/MMS 87–0119. 536p.

Turner, R.E. and Rao, Y.S., 1990. Relationships between wetland fragmentation and recent hydrologic changes in a deltaic coast. *Estuaries,* 13(3), 272–281.

Turner, R.E. and Streever, B., 2002. *Approaches to Coastal Wetland Restoration: Northern Gulf of Mexico*. Den Hague, Netherlands: SPB Academic Publishing, 147p.

Turner, R.E.; Swenson, E.M., and Lee, J.M., 1994. A rationale for coastal wetland restoration through spoil bank management in Louisiana. *Environmental Management,* 18(2), 271–282.

Turner, R.E.; Swenson, E.M., and Milan, C.S., 2000. Organic and inorganic contributions to vertical accretion in salt marsh sediments. *In:* Weinstein, M.; and Kreeger, D.A. (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Dordrecht, The Netherlands: Kluwer Academic, pp. 583–595.

Tweel, A.W. and Turner, R.E., 2012. Watershed land use and river engineering drive wetland formation and loss in the Mississippi River birdfoot delta. *Limnology and Oceanography,* 57(1), 18–28.

Tweel, A.W. and Turner, R.E., 2014. Contribution of tropical cyclones to the sediment budget for coastal wetlands in Louisiana, USA. *Landscape Ecology,* 29, 1083–1094.

Wiseman, W. J., Jr.; Swenson, E.M., and Power, J., 1990. Salinity trends in Louisiana estuaries. *Estuaries,* 13(3), 265–271.